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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 C.F.R. § 1.53(b))

Attorney Docket No.	E-1804
First Inventor or Application Identifier	Carrender et al.
Title	Phase Modulation in RF Tag
Express Mail Label No.	EK386615231US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: Assistant Commissioner for Patents
Box Patent Application
Washington, DC 20231

1. [X] * Fee Transmittal Form (e.g., PTO/SB/17) (Submit an original and a duplicate for fee processing)
2. [X] Specification [Total Pages 17] (preferred arrangement set forth below)
   - Descriptive title of the Invention
   - Cross References to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to Microfiche Appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings (if filed)
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
3. [X] Drawing(s) (35 U.S.C. 113) [Total Sheets 2]
4. Oath or Declaration [Total Pages 3]
   a. [X] Newly executed (original or copy)
   b. [ ] Copy from a prior application (37 C.F.R. § 1.63(d)) (for continuation/divisional with Box 16 completed)
      i. [ ] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 C.F.R. §§ 1.63(d)(2) and 1.33(b).

NOTE FOR ITEMS 1 & 13: IN ORDER TO BE ENTITLED TO PAY SMALL ENTITY FEES, A SMALL ENTITY STATEMENT IS REQUIRED (37 C.F.R. § 1.27), EXCEPT IF ONE FILED IN A PRIOR APPLICATION IS RELIED UPON (37 C.F.R. § 1.28).

5. [ ] Microfiche Computer Program (Appendix)
6. Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary)
   a. [ ] Computer Readable Copy
   b. [ ] Paper Copy (identical to computer copy)
   c. [ ] Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

7. [X] Assignment Papers (cover sheet & document(s))
8. [ ] 37 C.F.R.§3.73(b) Statement (when there is an assignee) [ ] Power of Attorney
9. [ ] English Translation Document (if applicable)
10. [ ] Information Disclosure Statement (IDS)/PTO-1449 [ ] Copies of IDS Citations
11. [ ] Preliminary Amendment
12. [X] Return Receipt Postcard (MPEP 503) (Should be specifically itemized)
13. [X] * Small Entity Statement(s) (PTO/SB/09-12) [ ] Statement filed in prior application, Status still proper and desired
14. [ ] Certified Copy of Priority Document(s) (if foreign priority is claimed)
15. [ ] Other: ....

16. If a CONTINUING APPLICATION, *check appropriate box, and supply the requisite information below and in a preliminary amendment:*

[ ] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No: ______/______

Prior application information: Examiner ______ Group / Art Unit: ______

For CONTINUATION or DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 4b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	)
CL Carrender, RW Gilbert	)
For: PHASE MODULATION IN RF TAG	) Our Ref. No: E-1804
	) Date: June 5, 2000

CERTIFICATE OF MAILING

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Dear Sir:

The undersigned hereby certifies that the attached:

[X] Patent Application of 17 pages, and
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PATENT
File No. E-1804

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant or Patentee: Curtis Lee Carrender and Ronald W. Gilbert

Serial or Patent No.: ____________________

Filed or Issued: ____________________

For: PHASE MODULATION IN RF TAG

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS
(37 CFR 1.9(f) and 1.27(d)) -

I hereby declare that I am an official empowered to act on behalf of the entity identified below:

NAME OF ORGANIZATION Battelle Memorial Institute
Pacific Northwest Division

ADDRESS OF ORGANIZATION Post Office Box 999, Richland, WA 99352

TYPE OF ENTITY:

[X] Nonprofit Organization (37 CFR 1.9(e))
Nonprofit Scientific or Educational Under Statute of State of the United States of America
(Name of State Ohio)
(Citation of Statute Sections 1719.01 and 1719.05, Rev. Code of Ohio)

[ ] Small Business (37 CFR 1.9(d))

[ ] Independent Inventor (37 CFR 1.9(c))

I hereby declare that the entity identified above qualifies as such as defined in [ ]37 CFR 1.9(c) [ ]37 CFR 1.9(d) [X]37 CFR 1.9(e) for purposes of paying reduced fees under section 41(a) and (b) of Title 35, United States Code with regard to the invention entitled PHASE MODULATION IN RF TAG by inventor(s) Curtis Lee Carrender and Ronald W. Gilbert described in

[ ] application executed ____________________

[X] specification filed herewith

[ ] application serial no. ______________, filed ______________

[ ] patent no. ____________________, issued ____________________.

I hereby state that rights under contract or law have been conveyed to and remain with entity with regard to the above identified invention.

If the rights held by such entity are not exclusive, each individual, concern or organization having rights in the invention must file separate statements as to their status as small entities (37 CFR 1.27) and that no rights to the invention are held by any person, other than the inventor, who could not qualify as an independent inventor under 37 CFR 1.9(c) if that person made the invention, or by any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

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NAME ______
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I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

NAME OF PERSON SIGNING Stephen R. May
TITLE OF ORGANIZATION Contracting Officer, Pacific Northwest Division, Battelle Memorial Institute
ADDRESS OF PERSON SIGNING Post Office Box 999, Richland, WA 99352

SIGNATURE Stephen R. May DATE June 6, 2000

PHASE MODULATION IN RF TAG

This invention was made with Government support under Contract DE-AC0676RLO1830 awarded by the U.S. Department of Energy. The Government has certain rights in the invention.

FIELD OF THE INVENTION

The present invention relates to radio frequency identification tags (RF tags), and in particular, to RF tags that communicate using phase modulation.

BACKGROUND OF THE INVENTION

Remote communication utilizing wireless equipment typically relies on radio frequency (RF) technology, which is employed in many industries. One application of RF technology is in locating, identifying, and tracking objects, such as animals, inventory, and vehicles.

RF identification (RFID) tag systems have been developed that facilitate monitoring of remote objects. As shown in Figure 1, a basic RFID system 10 includes two components: an interrogator or reader 12, and a transponder (commonly called an RF tag) 14. The interrogator 12 and RF tag 14 include respective antennas 16, 18. In operation, the interrogator 12 transmits through its antenna 16 a radio frequency interrogation signal 20 to the antenna 18 of the RF tag 14. In response to receiving the interrogation signal 20, the RF tag 14 produces an amplitude-modulated response signal 22 that is transmitted back to the interrogator 12 through the tag antenna 18 by a process known as backscatter.

The conventional RF tag 14 includes an amplitude modulator 24 with a switch 26, such as a MOS transistor, connected between the tag antenna 18 and ground. When the RF tag 14 is activated by the interrogation signal 20, a driver (not shown) creates a modulating signal 28 based on an information code, typically an identification code, stored in a non-volatile memory (not shown) of the RF tag 14. The modulating signal 28 is applied to a control terminal of the switch 26 which causes the switch 26 to alternately

open and close. When the switch 26 is open, the tag antenna 18 reflects a portion of the interrogation signal 20 back to the interrogator 12 as a portion 28 of the response signal 22. When the switch 26 is closed, the interrogation signal 20 travels through the switch 26 to ground, without being reflected, thereby creating a null portion 29 of the response signal 22. In other words, the interrogation signal 20 is amplitude-modulated to produce the response signal 22 by alternately reflecting and absorbing the interrogation signal 20 according to the modulating signal 28, which is characteristic of the stored information code. The RF tag 14 could also be modified so that the interrogation signal is reflected when the switch 26 is closed and absorbed when the switch 26 is open. Upon receiving the response signal 22, the interrogator 12 demodulates the response signal 22 to decode the information code represented by the response signal.

The substantial advantage of RFID systems is the non-contact, non-line-of-sight capability of the technology. The interrogator 12 emits the interrogation signal 20 with a range from one inch to one hundred feet or more, depending upon its power output and the radio frequency used. Tags can be read through a variety of substances such as smell, fog, ice, paint, dirt, and other visually and environmentally challenging conditions where bar codes or other optically-read technologies would be useless. RF tags can also be read at remarkable speeds, in most cases responding in less than one hundred milliseconds.

A typical RF tag system 10 will contain a number of RF tags 14 and the interrogator 12. There are three main categories of RF tags. These are beam-powered passive tags, battery-powered semi-passive tags, and active tags. Each operates in fundamentally different ways.

The beam-powered RF tag is often referred to as a passive device because it derives the energy needed for its operation from the interrogation signal beamed at it. The tag rectifies the field and changes the reflective characteristics of the tag itself, creating a change in reflectivity that is seen at the interrogator. A battery-powered semi-passive RFID tag operates in a similar fashion, modulating its RF cross section in order to reflect a delta to the interrogator to develop a communication link. Here, the battery is the source of

the tag's operational power. Finally, in the active RF tag, a transmitter is used to create its own radio frequency energy powered by the battery.

The range of communication for such tags varies according to the transmission power of the interrogator 12 and the RF tag 14. Battery-powered tags operating at 2,450 MHz have traditionally been limited to less than ten meters in range. However, devices with sufficient power can reach up to 200 meters in range, depending on the frequency and environmental characteristics.

Conventional continuous wave backscatter RF tag systems utilizing passive (no battery) RF tags require adequate power from the interrogation signal 20 to power the internal circuitry in the RF tag 14 used to amplitude-modulate the response signal 22 back to the interrogator 12. While this is successful for tags that are located in close proximity to an interrogator 12, for example less than three meters, this may be insufficient range for some applications, for example, which require greater than 100 meters.

SUMMARY OF THE INVENTION

An embodiment of the present invention is directed to an RF communication system that employs phase-modulated backscatter signals for RF communication from an RF tag to an interrogator. The interrogator transmits a continuous wave interrogation signal to the RF tag, which based on an information code stored in a memory, phase-modulates the interrogation signal to produce a backscatter response signal that is transmitted back to the interrogator. By employing a phase-modulated backscatter response signal rather than the amplitude-modulated backscatter response signal of prior art systems shown in Figure 1, the RF communication system is able to reflect much more power from the interrogation signal than is possible using the prior art systems, resulting in a much longer communication range between the interrogator and RF tag.

In one embodiment, the phase modulator structure in the RF tag includes a switch having a control terminal and first and second conduction terminals, the first conduction terminal being coupled to an antenna in the RF tag; a quarter-wavelength stub coupled to the second conduction terminal of the switch; and a driver coupled between the

memory and the control terminal of the switch. The driver is structured to produce a modulating signal corresponding to the information code, the modulating signal alternately opening and closing the switch. Opening and closing the switch changes the phase of the response signal by respectively decreasing and increasing the transmission path taken by the interrogation signal before being reflected as the response signal.

In another embodiment, the phase modulator includes a diode coupled to the antenna and a driver coupled between the memory and the diode. The driver again is structured to produce a modulating signal corresponding to the information code, the modulating signal being a variable voltage that modulates an impedance of the diode. By modulating the impedance of the diode, the phase of the response signal reflected by the diode and antenna is modulated.

An embodiment of the invention is also directed to an RF tag and a method that phase-modulates the interrogation signal to produce and transmit the response signal.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic diagram of a prior art RF communication system employing amplitude-modulated backscatter signals.

Figure 2 is a schematic diagram of an RF communication system employing phase-modulated backscatter signals according to an embodiment of the present invention.

Figure 3A is a schematic diagram of an RF tag for employment with the RF communication system shown in Figure 2.

Figure 3B is a graph showing the voltage-capacitance relationship for a diode used in the embodiment shown in Figure 3A.

Figure 4 is an alternate embodiment of an RF tag that can be employed in the RF communication system shown in Figure 2.

Figure 5 is a circuit diagram of an alternate RF tag that can be employed in the RF communication system shown in Figure 2.

DETAILED DESCRIPTION OF THE INVENTION

As shown in Figure 2, an embodiment of the present invention is directed to an RF communication system 30 that employs phase-modulated backscatter signals. The RF communication system 30 includes a reader or interrogator 32 that includes an antenna 34 through which the reader transmits a continuous wave interrogation signal 36 to an RF tag 38. Based on an identification code stored in a memory (not shown) of the RF tag 38, the RF tag phase-modulates the interrogation signal 36 to produce a backscatter response signal 40 that is transmitted back to the interrogator 32.

By employing a phase-modulated backscatter response signal 40 rather than the amplitude-modulated backscatter response signal of the prior art system shown in Figure 1, the RF communication system 30 is able to reflect much more power from the interrogation signal 36 than is possible using the prior art system of Figure 1. That is because the RF tag 38 is always reflecting the interrogation signal 36 to produce the response signal 40. In contrast, the amplitude-modulated response signal of the prior art system is only ON essentially half of its transmission, depending on the coding employed, resulting in less power and a lower signal-to-noise ratio. As a result, the RF communication system 30 has a much longer range than the prior art system shown in Figure 1.

In the embodiment shown in Figure 2, the RF tag 38 includes an antenna 42 coupled to a phase modulator 44. The phase modulator 44 includes a switch 46 coupled between the antenna 42 and a partial-wavelength stub 48. The switch 46 is shown in Figure 2 as an N-channel MOS transistor, but it will be understood that a P-channel MOS transistor, a bipolar transistor, or numerous other types of switches could be employed instead. The partial-wavelength stub 48 can be a quarter-wavelength ($\lambda/4$) stub, a $\lambda/8$ stub, or any other length stub depending upon the amount of phase change desired for the phase modulation performed by the phase modulator 44.

In Figure 2, a modulating signal 50 is input to a control terminal of the switch 46 to alternately open and close the switch according to an identification code that is stored in a non-volatile memory (not shown) of the RF tag 38. When the modulating signal

50 opens the switch 46, the interrogation signal 36 is received by the antenna 42 and is reflected off of the switch 46 back through the antenna 42 to produce portions 51 of the response signal 40 that are in phase with the interrogation signal 36. When the modulating signal 50 closes the switch 46, the interrogation signal 36 travels through the antenna 42 and switch 46 to the phase changer 48 which reflects the signal back through the switch 46 and antenna 42 to produce portions 52 of the response signal 40 having a different phase than the interrogation signal 36. The different phase is due to the increased signal path through the switch 46 and phase changer 48 in both directions before being reflected back through the antenna 42.

It will be appreciated that the depiction of the RF tag 38 in Figure 2 does not include such structures as the memory that stores the identification code for the RF tag, and the circuit elements that produce the modulating signal 50, as those elements are well known in the art and no changes to those structures are needed to implement the RF tag 38. For example, U.S. Patent No. 4,075,632 to Baldwin et al., which is incorporated by reference herein in its entirety, discusses in detail circuit structures that could be used to produce the modulating signal 50. An implementation of the RF tag 38 employs a quarter-wave dipole antenna as the antenna 42, but any type of antenna could be employed.

The internal structures of the interrogator 32 are not shown in Figure 2 as no changes are needed to known prior art readers for implementation of the RF communication system 30. For example, the interrogator 32 can be the multichannel homodyne receiver described in U.S. Patent No. 4,360,810 to Landt, which is incorporated by reference herein in its entirety.

Shown in Figure 3A is an alternate RF tag 38A that could be employed in the RF communication system 30 in place of the RF tag 38 shown in Figure 2. The RF tag 38A includes an alternate phase modulator 44A coupled to the same antenna 42 as in the RF tag 38. The phase modulator 44A includes a diode 53 that is coupled at one end to the antenna 42 and at an opposite end to the driver (not shown) that drives the diode 53 with the modulating signal 50.

The operation of the phase modulator 44A can be understood with respect to Figure 3B which shows the voltage to capacitance relationship of the diode 53. Figure 3B shows that when the voltage input into the diode 53 is relatively high, the capacitance of the diode is low and when the voltage is at a relatively low level, then the capacitance of the diode 53 is high. Such changes in capacitance of the diode 53 based on the changing voltage of the modulating signal 50 causes phase changes in the response signal 40 compared to the interrogation signal 36. It will be recognized that any number of diodes could be employed in addition to the diode 53 and the diodes could be biased in either direction.

Shown in Figure 4 is an another RF tag 38B that could be employed in the RF communication system 30 in place of the RF tag 38 shown in Figure 2. The RF tag 38B includes an alternate phase modulator 44B coupled to the same antenna 42 as in the RF tag 38. The phase modulator 44B includes a first diode 53A that is coupled at one end to the antenna 42 and at an opposite end to the driver (not shown) that drives the first diode 53A with the modulating signal 50. The phase modulator 44B also includes a second diode 53B coupled between the antenna 42 and a parallel RC circuit 54 comprised of a resistor 56 connected in parallel with a capacitor 58 between the second diode 53B and ground. A quarter-wavelength stub 60 is also coupled to the node between the second diode 53B and the parallel RC circuit 54. The concepts underlying the operation of the phase modulator 44B are identical to those discussed above with respect to the phase modulators 44, 44A of Figures 2, 3A.

Shown in Figure 5 is an another RF tag 38C that could be employed in the RF communication system 30 in place of the RF tag 38 shown in Figure 2. The RF tag 38C includes an alternate phase modulator 44C coupled between a memory 62 and the same antenna 42 as in the RF tag 38. In contrast to the phase modulators 44, 44A, 44B of Figures 2-4, the phase modulator 44C produces a response signal 98 that includes four different phases: 0°, 45°, 90°, and 135° (λ, $\lambda/8$, $\lambda/4$, $3\lambda/8$).

The phase modulator 44C includes a processor 64, such as a general purpose microprocessor, having a first input/output (I/O) port 66 coupled to the memory by a

plurality of individual bit lines 68 and a second I/O port 70. The phase modulator 44C also includes first, second, and third phase changers 72, 74, 76 having respective switches 78, 80, 82 and respective partial-wavelength stubs 84, 86, 88. The second I/O port 70 of the processor 64 is coupled to the first, second, and third switches 78, 80, 82 by first, second, and third bit lines 90, 92, 94, respectively. In one embodiment, the partial-wavelength stubs 84, 86, 88 are three-eighth-, quarter-, and eighth-wavelength stubs, respectively. The switches 78-82 are shown as MOS transistors, but numerous other known switches could be employed instead. The processor 64 is clocked by an oscillator 96 to provide for the timing of the operations to be discussed below.

Stored in the memory 62 is an information code, such as an identification code that identifies the RF tag 38C and/or an object to which the RF tag is attached. Alternatively, the information code could represent numerous other pieces of information, such as the environmental conditions surrounding the RF tag 38C, inventory information associated with the RF tag, or information that was previously written to the RF tag before or after the RF tag was placed into service. The memory 62 can be implemented with any type of memory, but preferably is non-volatile memory so that the information code is not lost when power is lost.

In response to being activated by the interrogation signal 36, the processor 64 retrieves the information code from the memory 62. Based on the information code retrieved, the processor 64 modulates the interrogation signal 36 by alternately selecting one or none of the switches 78-82. If none of the switches 78-82 are selected, then a portion of the interrogation signal 36 is reflected with no change in phase. If the first switch 78 is selected, then the portion of the interrogation signal 36 is reflected with a 3/8-wavelength (135°) phase change; if the second switch 80 is selected, the phase change is 1/4-wavelength (90°); and if the third switch 82 is selected, the phase change is 1/8-wavelength (45°). String together the different phase portions (including the no phase change portion) at a modulating frequency determined by the oscillator 96 produces a response signal 98 that is transmitted back to the interrogator.

One large advantage provided by the RF tag 38C shown in Figure 5 is that the information stored in the memory 62 can be transmitted on the response signal 98 parallel or multi-bit form. For example, to transmit the number 3, the processor can simply select the third switch 82 to transmit a portion of the response signal 98 with a phase change of 45° compared to the interrogation signal 36. In contrast, to transmit the same number 3 using the prior art RF tag 10 of Figure 1, one would transmit two portions representing ones (3 = 11 in binary). As a result, the RF tag 38C can transmit twice as much information as the prior art RF tag 10 within the same signal period.

It should be appreciated that the structure of the RF tag 38C of Figure 5 is exemplary only, and numerous alterations can be made without departing from the invention. Theoretically, an infinite number of different phases can be incorporated into the response signal 98, although as a practical matter, it may be very difficult to distinguish more than about 32 different phases using current technology. However, the invention is intended to be broad enough to include any number of different phases. In addition, rather than employing plural discrete phase changers 72-76, one could employ a known, commercially available phase modulator chip to provide the respective phase changes.

CLOSURE

In view of the foregoing, it will be appreciated that the RF tags discussed herein provide important advantages over prior art RF tags. In particular, phase modulating the interrogation signals produces a stronger response signals with higher signal to noise ratios than the amplitude-modulating prior art tags. In addition, phase modulation allows plural bits of information to be transmitted in the same signal space as the prior art tags. As a result, the RF tags of the present invention provide faster information exchange over much longer distances than the prior art tags.

Finally it will be clear that many modifications and variants may be introduced to the inventive embodiments described and illustrated herein, all of which come within the scope of the invention as defined in the accompanying claims.

CLAIMS

We claim:

1. A radio frequency transponder, comprising:

an antenna for receiving an interrogation signal;

a memory that stores an information code; and

a phase modulator coupled to the antenna and memory, the phase modulator being structured to produce a backscatter response signal by phase modulating the interrogation signal according to the information code.

2. The transponder of claim 1 wherein the phase modulator includes:

a switch having a control terminal and first and second conduction terminals, the first conduction terminal being coupled to the antenna;

a quarter-wavelength stub coupled to the second conduction terminal of the switch; and

a driver coupled between the memory and the control terminal of the switch, the driver being structured to produce a modulating signal corresponding to the information code, the modulating signal alternately opening and closing the switch.

3. The transponder of claim 2 wherein the driver includes a microprocessor.

4. The transponder of claim 1 wherein the phase modulator includes a diode coupled to the antenna and a driver coupled between the memory and the diode, the driver being structured to produce a modulating signal corresponding to the information code, the modulating signal being a variable voltage that modulates a capacitance of the diode to phase modulate the interrogation signal and thereby produce the response signal.

5. The transponder of claim 4 wherein the driver includes a microprocessor.

6. The transponder of claim 1 wherein the phase modulator includes:

a first diode having first and second ends, the second end being coupled to the antenna;

a second diode having first and second ends, the first end being coupled to the antenna and the second end of the first diode;

a quarter-wavelength stub coupled to the second end of the second diode;

a parallel RC circuit coupled between the stub and a reference voltage; and

a driver coupled between the memory and the first end of the first diode, the driver being structured to produce a modulating signal corresponding to the information code.

7. The transponder of claim 1 wherein the phase modulator is structured to include in the response signal a plurality of phases in addition to a phase that is substantially identical to a phase of the interrogation signal.

8. The transponder of claim 1 wherein the phase modulator includes first and second phase changers that produce in the response signal respective first and second phases that are each different than a phase of the interrogation signal.

9. The transponder of claim 8 wherein the phase modulator further includes a third phase changer that produces in the response signal a third phase that is different than the phase of the interrogation signal, each of the phase changers include a switch coupled between the antenna and a stub having a length other than a wavelength of the interrogation signal.

10. A radio frequency communication system, comprising:

an interrogator that transmits a radio frequency interrogation signal and receives a backscatter response signal; and

a transponder that receives the interrogation signal and transmits the response signal to the interrogator, the transponder including:

a memory that stores an information code; and

a phase modulator coupled to the memory and structured to produce the response signal by phase modulating the interrogation signal according to the information code.

11. The communication system of claim 10 wherein the transponder includes an antenna that receives the interrogation signal and transmits the response signal and the phase modulator includes:

a quarter-wavelength stub;

a switch coupled between the stub and the antenna and having a control terminal; and

a driver coupled between the memory and the control terminal of the switch, the driver being structured to produce a modulating signal corresponding to the information code, the modulating signal alternately opening and closing the switch.

12. The communication system of claim 10 wherein the transponder includes an antenna that receives the interrogation signal and transmits the response signal and the phase modulator includes a diode coupled to the antenna and a driver coupled between the memory and the diode, the driver being structured to produce a modulating signal corresponding to the information code, the modulating signal being a variable voltage that modulates an impedance of the diode to phase modulate the interrogation signal and thereby produce the response signal.

13. The communication system of claim 10 wherein the transponder includes an antenna that receives the interrogation signal and transmits the response signal and the phase modulator includes:

a first diode having first and second ends, the second end being coupled to the antenna;

a second diode having first and second ends, the first end being coupled to the antenna and the second end of the first diode;

a quarter-wavelength stub coupled to the second end of the second diode;

a parallel RC circuit coupled between the stub and a reference voltage; and

a driver coupled between the memory and the first end of the first diode, the driver being structured to produce a modulating signal corresponding to the information code.

14. The communication system of claim 10 wherein the phase modulator is structured to include in the response signal a plurality of phases in addition to a phase that is substantially identical to a phase of the interrogation signal.

15. The communication system of claim 10 wherein the phase modulator includes first and second phase changers that produce in the response signal respective first and second phases that are each different than a phase of the interrogation signal.

16. The communication system of claim 15 wherein the transponder includes an antenna that receives the interrogation signal and transmits the response signal and the phase modulator further includes a third phase changer that produces in the response signal a third phase that is different than the phase of the interrogation signal, each of the phase changers include a switch coupled between the antenna and a stub having a length other than a wavelength of the interrogation signal.

17. A radio frequency transponder, comprising:

means for receiving a radio frequency interrogation signal from an interrogator;

means for phase modulating the interrogation signal according to an information code to produce a response signal; and

means for transmitting the response signal.

18. The transponder of claim 17 wherein the phase modulating means include:

stub means having a length other than a wavelength of the interrogation signal;

a switch coupled to the stub means and having a control terminal; and

signal producing means for producing a modulating signal corresponding to the information code, the modulating signal being applied to the control terminal of the switch to alternately open and close the switch.

19. The transponder of claim 18 wherein the signal producing means include a memory that stores the information code and processing means coupled to the memory, the processing means being for producing the modulating signal as a function of the information code.

20. The transponder of claim 17 wherein the phase modulating means include diode means and driver means for producing and applying to the diode means a modulating signal corresponding to the information code, the modulating signal being a variable voltage that modulates an impedance of the diode means to phase modulate the interrogation signal and thereby produce the response signal.

21. The transponder of claim 20 wherein the signal producing means include a memory that stores the information code and processing means coupled to the

memory, the processing means being for producing the modulating signal as a function of the information code.

22. The transponder of claim 20 wherein the phase modulating means include:

a first diode coupled to the transmitting means;

a second diode coupled to the antenna and the first diode;

a quarter-wavelength stub coupled to the second diode;

a parallel RC circuit coupled between the stub and a reference voltage; and

driver coupled to the first diode, the driver means being for producing and applying to the first diode a modulating signal corresponding to the information code.

23. The transponder of claim 17 wherein the phase modulating means include first and second phase changers that produce in the response signal respective first and second phases that are each different than a phase of the interrogation signal.

24. The transponder of claim 23 wherein the phase modulating means further include a third phase changer that produces in the response signal a third phase that is different than the phase of the interrogation signal, each of the phase changers including a switch coupled between the antenna and a stub having a length other than a wavelength of the interrogation signal.

25. A method of radio frequency communication, the method comprising:

receiving a radio frequency interrogation signal from an interrogator;

phase modulating the interrogation signal according to an information code to produce a response signal; and

transmitting the response signal.

26. The method of claim 25 wherein the phase modulating step includes:

alternately opening and closing a switch according to a modulating signal corresponding to the information code, the switch being coupled between an antenna that transmits the response signal and a stub that has a length other than a wavelength of the interrogation signal.

27. The method of claim 25 wherein the phase modulating step includes producing a modulating signal corresponding to the information code, the modulating signal being a variable voltage that modulates a capacitance of a diode to phase modulate the interrogation signal and thereby produce the response signal.

28. The method of claim 25 wherein the phase modulating step includes producing in the response signal a plurality of phases that are each different than a phase of the interrogation signal.

ABSTRACT

A radio frequency (RF) communication system employs phase-modulated backscatter signals for RF communication from an RF tag to an interrogator. The interrogator transmits a continuous wave interrogation signal to the RF tag, which based on an information code stored in a memory, phase-modulates the interrogation signal to produce a backscatter response signal that is transmitted back to the interrogator. A phase modulator structure in the RF tag may include a switch coupled between an antenna and a quarter-wavelength stub; and a driver coupled between the memory and a control terminal of the switch. The driver is structured to produce a modulating signal corresponding to the information code, the modulating signal alternately opening and closing the switch to respectively decrease and increase the transmission path taken by the interrogation signal and thereby modulate the phase of the response signal. Alternatively, the phase modulator may include a diode coupled between the antenna and driver. The modulating signal from the driver modulates the capacitance of the diode, which modulates the phase of the response signal reflected by the diode and antenna.

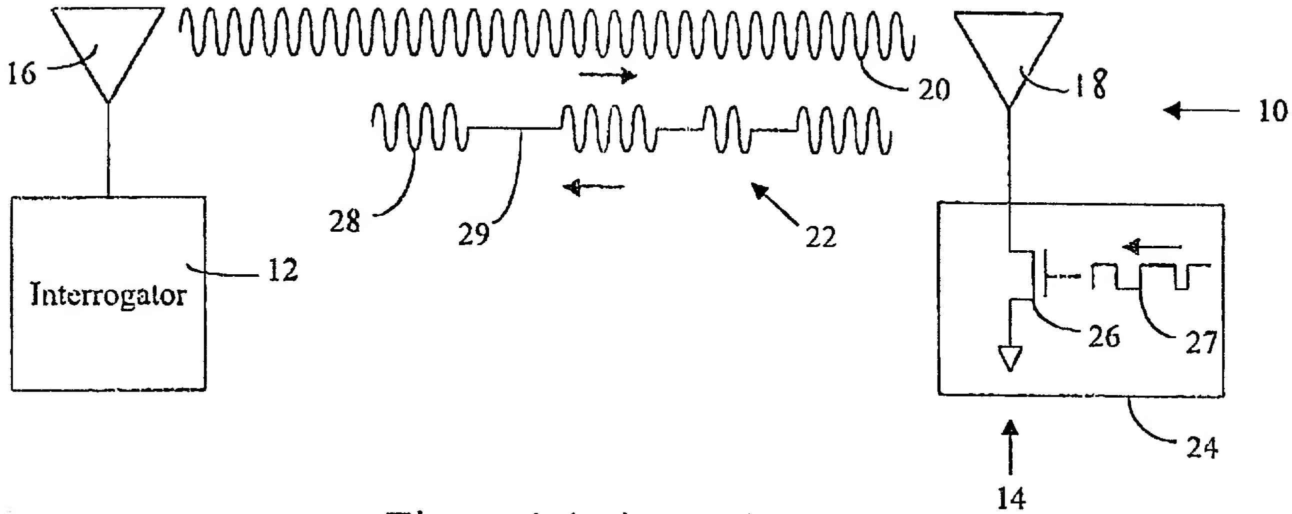

Figure 1 (Prior Art)

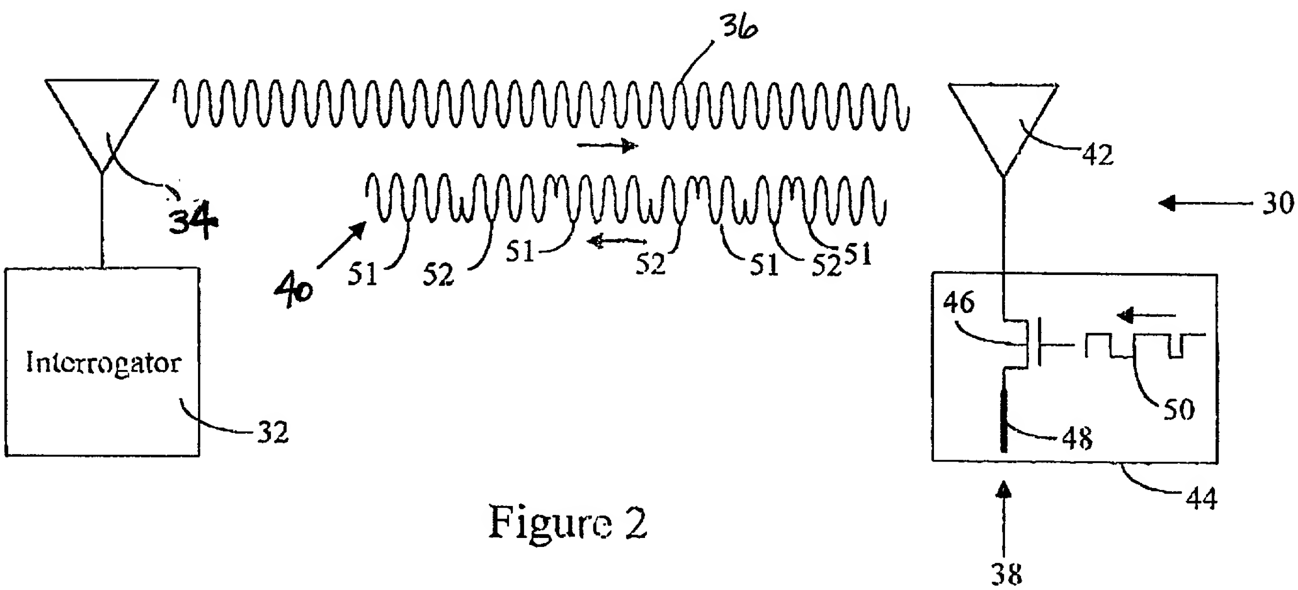

Figure 2

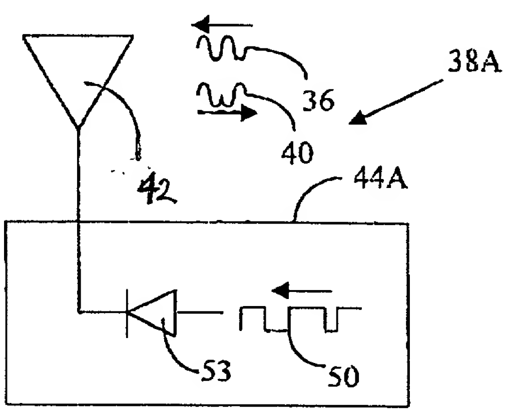

Figure 3A

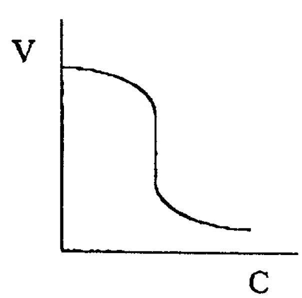

Figure 3B

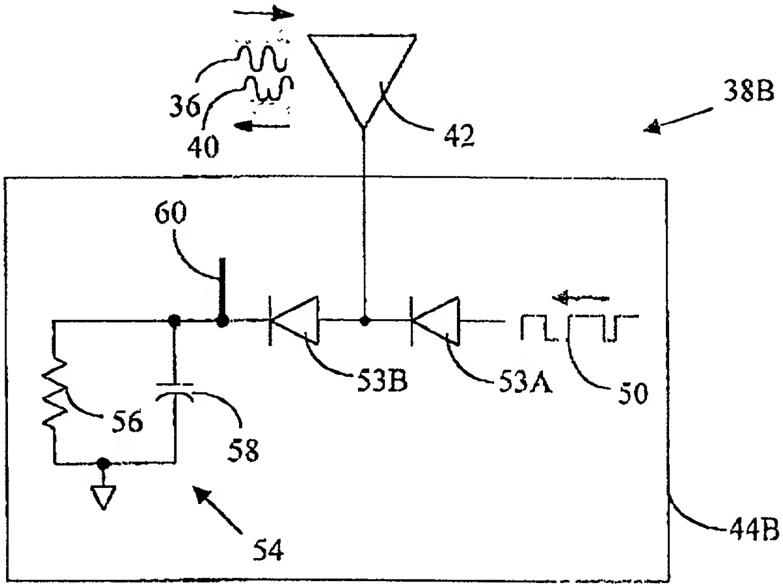

Figure 4

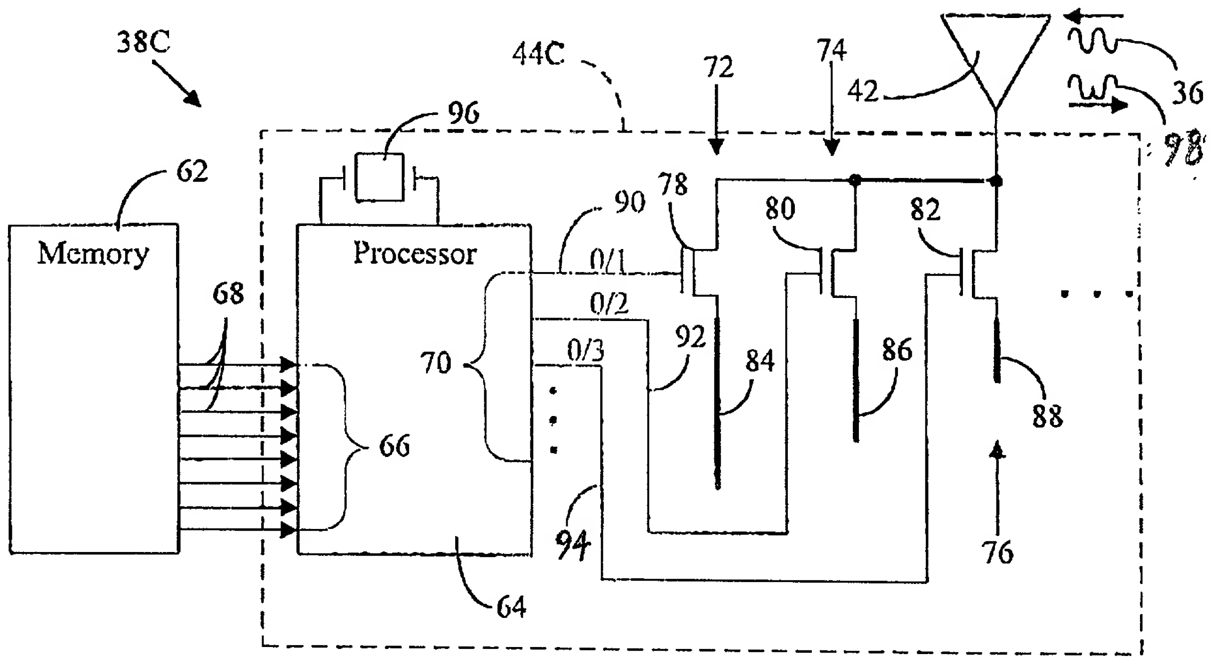

Figure 5

Express Mailing Label #EK386615231US

PATENT

File No. E-1804

COMBINED DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name,

I believe I am an original, first, and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled PHASE MODULATION IN RF TAG, the specification of which

[X] is attached hereto.

[ ] was filed on ______________ as Application Serial No. _______

[ ] and was amended on ______________________________ (if applicable)

[ ] with amendments through ______________________________. (if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, Sec. 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, Sec. 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

[X] no such applications have been filed

[ ] such applications have been filed as follows

Prior Foreign Application(s) | Priority Claimed

NONE

(Number)	(Country)	(Day/Month/Year Filed)	[ ] Yes	[ ] No
(Number)	(Country)	(Day/Month/Year Filed)	[ ] Yes	[ ] No

I hereby claim the benefit under Title 35, United States Code, Sec. 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Sec. 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, Sec. 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

NONE

(Application Serial No.)	(Filing Date)	(Status - patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status - patented, pending, abandoned)

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application, to file a corresponding international application, and to transact all business in the Patent and Trademark Office connected therewith:

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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